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Students' Knowledge gains, Self-efficacy, Perceived Level of Engagement, and Perceptions with regard to Home-based Biology Experiments (HBEs)

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ABSTRACT
Home-based biology experiments (HBEs) are practical learning activities that allow students to perform safe and relevant experiments at home. Motivated by the need to innovate teaching approaches in science education due to the COVID-19 pandemic, this study was conducted to determine the effects of home-based biology experiments (HBEs) on their knowledge gains, self-efficacy, and perceived level of engagement. In addition, students' teachers' and parents' feedback were also investigated. This study employed a quasi-experimental research design using a mixed-method approach involving a pre-test/post-test design in which ten teacher-collaborators and 836 pupils participated. Fifteen-item teacher-made parallel tests and the 38-item perceptions, self-efficacy and engagement questionnaire were distributed via Google Forms. Results revealed that most participants strongly agreed that HBEs were lesson congruent and risk-free, the materials were readily available, and it was fun and challenging ($M=3.56$, $SD=0.77$). Moreover, HBEs were found to be effective in improving pupils' knowledge gains ($T=119$, $z=-4.56$, $p=0.04$), self-efficacy ($M=3.36$, $SD=0.71$), and perceived level of engagement ($M=3.45$, $SD=0.69$). Responses were significantly different when grouped according to grade level, gender, and type of HBEs used. The results of thematic analysis were categorised as "Affordances" and "Constraints". Six subthemes emerged from the Affordances : "Safety", "Feasibility", "Independent Learning", "Learning Material", and "Affordability", while there were four subthemes for "Constraints": "Expenses", "Student Interaction", "Availability", and "Time Management". It can be concluded that home-based biology experiments are effective and relevant teaching strategies to deliver practical learning in the distance learning modality.

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Introduction

Laboratory experimentation has long been an essential component in the teaching and learning of biology. Experiments provide learning opportunities for school students to test their hypotheses, and apply the concepts they learned in class (Journey, 2019). The COVID-19 pandemic disrupted the education system all over the world (UNESCO, 2020). The Philippine government ordered the closure of school laboratories and facilities for the safety of pupils and school personnel (DepEd, 2020). These actions impede the standard process of providing experiential and practical activities in the teaching and learning of biology. Science teachers were obliged to switch to remote teaching and conduct virtual classes. This was a challenge for teachers as they had to simultaneously manage teaching and learning of abstract concepts and practical aspects in an online environment. Consequently, teachers had to redesign experimental activities for the remote learning environment (Babinčáková et al., 2020; Lapada et al., 2020).

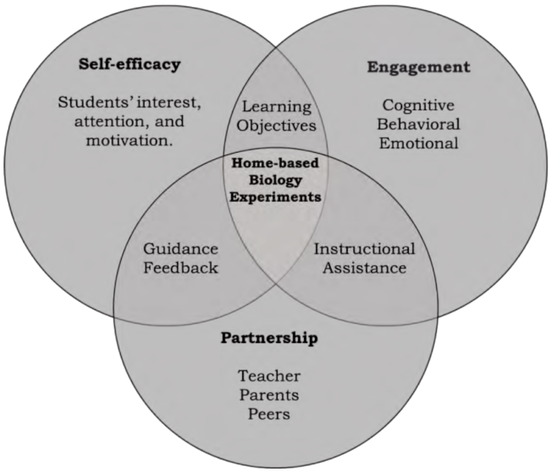
Simulation-based experiments, including *BioInteractive, Bioman, Phet Simulations*, and many more, are commonly used by science educators as alternatives to hands-on laboratory activities in teaching biology (Ma et al., 2006; Nafidi et al., 2018; Robledo & Prudente, 2020). Several studies have utilised other teaching resources as alternative activities for remote learning, such as remote laboratories using the available tools and equipment (Pekdag, 2010; Lowe et al., 2013), live demonstrations of experiments, printed guides, and video-guided experiments (Pasquali, 2007). These studies agreed that these teaching resources effectively taught the practical aspects of biology, improving pupils' motivation (Chittum et al., 2017; Sasmito et al., 2022) and their attitudes towards science (Fulmer et al., 2019; Robledo & Prudente, 2022). However, other studies have revealed that the use of these resources may have shortcomings. For instance, pupils found the simulation-based activities disorienting and disappointing due to prolonged screen time and eye strain (Ramos-Mocrillo, 2020). Rebenitsch et al. (2016) explained that the use of simulation-based activities could result in symptoms of cybersickness, such as fatigue, blurred vision, nausea and headache. Online simulation-based activities would obviously not be the best option for pupils who do not have a strong internet connection. All authors suggested having variation in teaching strategies, being careful in modifying experiments, and conducting further research on the use of remote teaching materials.

Vasiliadou (2020) and Sari et al. (2020) stressed that online laboratories could not replace in-person experimentation in conventional laboratories entirely. In this time of disruption, it is necessary to come up with innovative new teaching methods and strategies to address these challenges to education (Das et al., 2020). This study utilised home-based biology experiments (HBEs) as alternative learning activities to teach the practical aspects of biology using household materials and tools. HBEs as learning materials require the following features: they must not present any safety issues or risks, they must require no special equipment, and they should deliver an authentic learning experience that allows the learners to reflect on the outcomes. There should be defined roles for parents or guardians who are recognised as home-based laboratory supervisors who monitor their child's performance and ensure safety throughout the procedure and the materials should be modifiable (Robledo, 2021).

As shown in Figure 1, home-based biology experiments involve the collaboration of parents, teachers, and learners.. Topor et al. (2010) reported that parental involvement positively correlated with learners' academic performance. As discussed, HBEs promote parental engagement by explicitly describing the roles of parents and guardians in the implementation (Appendix A). In addition, There is a need for a continuous line of communication between the parents and teachers to ensure safety, coordination of tasks, and immediate reporting of accidents (Robledo, 2021; see also Appendix A). Assessing pupils' knowledge gains is an important way of evaluating teaching and learning interventions and strategies. Their conceptual understanding of the topic or subject matter demonstrates their academic performance and the effectiveness of a chosen approach. To validate further the results, students' test scores and The effects of HBEs on sudents' perceptions, self-efficacy, and level of engagement were also investigated. Learners' perceptions are an essential determinant of their learning behaviours (Wang et. al, 2013). In this study, the pupils' perceptions were classified into three dimensions: general features, congruence with the lesson, and pupils' learning experiences. Self-efficacy, as generally described in Bandura's Theory, is one's belief in his or her potential and ability to achieve objectives or learning outcomes (Bandura, 1991). Pupils with a stronger sense of self-efficacy are expected to face more challenging tasks by themselves and be innately motivated (Margolis et al., 2006). Fencl et al. (2005) noted that variation in teaching strategies and learning activities could improve students' self-efficacy.

Figure 1

Theoretical Framework of the Study



Learners' active engagement is a major contributing factor to their academic performance (Maltese et al., 2010). Pupil engagement is the participation, interest, attention, and desire of learners that keep them in touch with their learning (Beri and Stanikzai, 2019). Fredricks et al. (2004) classified the engagement levels of learners into three interrelated components: cognitive engagement, behavioural engagement, and emotional engagement. Cognitive engagement refers to the use of cognitive strategies in understanding complex ideas (Zimmerman, 1990). Behavioural engagement is defined as positive conduct and the absence of disruptive behaviour among pupils as they participate in a class (Fredricks et al., 2004). Finn (1989) distinguished emotional engagement as the presence of positive emotional responses to classroom activities or learning events, including appreciating learning and gaining interest in the learning activity. According to Beri et al. (2019), learners' self-efficacy and engagement can be improved by having well-articulated and attainable learning objectives. Appleton et al. (2008) stressed that assessment of the engagement levels of the students is a vital part of the validation and evaluation of learning materials. Thus, these components were considered essential in this study to determine how HBEs improve students' self-efficacy and engagement levels.

The utilisation of home-based activities has been widely investigated as an alternative learning activity in teaching various science courses. Neves et al. (2017) determined the perceptions of high school students from Brazil in performing home-based activity vs. laboratory activity in learning human physiology. Their results showed that both learning activities were significantly effective in learning human physiology. In the UK, Bishop et al. (2021) investigated the experiences of college students in performing home-based practical experiments during the COVID-19 pandemic. They found that students reported positive overall experiences in performing engineering experiments. However, several challenges were encountered including the unavailability of materials, and the unfamiliarity with the procedures due to lack of demonstration. In a recent case study by Santiago et al. (2022) in Spain, the perceptions of pupils in performing home-based experiments in chemical kinetics was investigated. Although their perceptions of the activities had not changed after performing the experiments, they found that learning outcomes were still met by students who did the activity at home and in the lab. In the Philippine context, a phenomenological study was conducted by Cahapay & Labrador (2021) to analyse the lived experiences of teachers in remote science education during the COVID-19 crisis. Several difficulties emerged during the implementation such as the lack of practical activities and the poor quality of instructional materials. Sanchez et al. (2021) performed a study to determine the feasibility of conducting a laboratory experiment on natural acid-base indicators as a home-based activity. They found that although at-home activities are feasible and satisfying, there were errors and discrepancies in the outcomes of the experiments.

There were several gaps that were identified based from the findings of the previously published international and local studies on home-based science activities. Only learners' perceptions were included in the previous studies, none of which included teachers' and parents' experiences and perceptions. Variables focused primarily on pupils' perceptions and satisfaction, neglecting other essential variables or domains of their learning (cognitive, affective and psychomotor). Moreover, there were controversies and unclear evidence of the effectiveness of utilising home-based activities in teaching and learning science. Further research on the effectives of HBEs as alternative learning activities is timely and relevant because it may provide a clearer perspective and better understanding of its pedagogical implications and importance in these challenging times. Thus, this study aimed to determine school students' knowledge gains, self-efficacy, and engagement, and perceptions with regard to the use of home-based biology experiments as learning activity for distance learning. Additionally, the study wanted to determine the relationships of these variables and the affordances and constraints of using HBEs, and the feedback of the teachers and parents on the implementation of HBEs.

Methodology

Research Design

The study employed a quasi-experimental research design using a mixed-method approach (Cook & Campbell, 1979) involving a pretest/posttest design (see Figure 2). Pupils' knowledge gains were studied by comparing the results of the pre- and post-test questionnaires. The self-efficacy, engagement, and perceptions of all participants (N = 839) were investigated using the post-test questionnaire results only. Moreover, pupils' and teachers' feedback were collected using focus group discussions.

Figure 2

Research Design and Components of The Study

G	O_1 ········▸	X ········▸	O_2
	Pre-test -Students' prior knowledge about the specific topic (Dependent variable)	Implementation of Home-based Biology Experiments (Intervention)	Post-test -Perceptions Questionnaire -Self-efficacy Questionnaire -Engagement Questionnaire -Focus Group Discussion

Research Participants

A "Call for Collaboration" was launched during the webinar series spearheaded by an institutional chapter of the Biology Teachers Association of the Philippines (BIOTA) on December 17, 2020. Ten science teachers and 839 school students at different grade levels of various private and public schools agreed to volunteer in the study. Furthermore, 839 students participated in the study by performing one experiment each. Most of the respondents were female (56.7%) and were studying in public schools (70.4%). Students were from different levels from Grade 5 to Grade 11, with most respondents coming from Grade 7 (34.2%) and the fewest coming from Grade 8, with only 3.4%. There were no Grade 6 or Grade 12 respondents. Moreover, 212 parents participated in the series of focus group discussions

Figure 3

Students' Distribution According to Gender

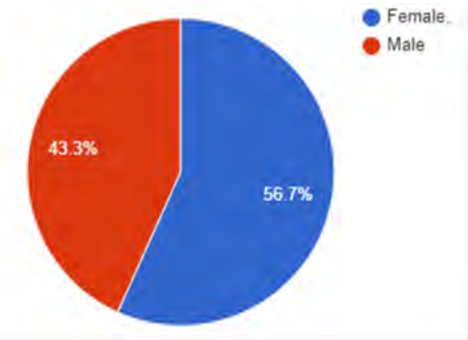


Figure 4

Students' Distribution According to Type of School

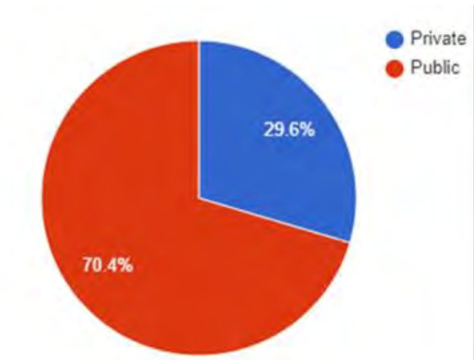
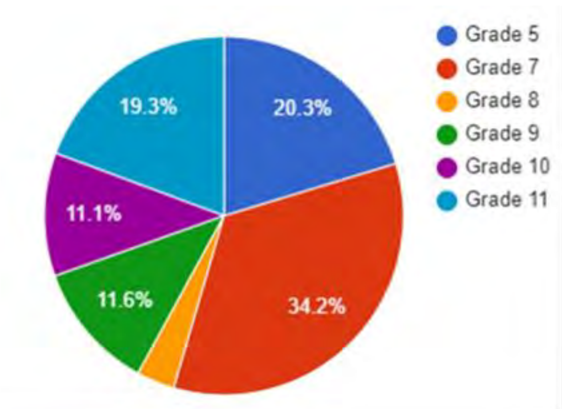


Figure 5

Students' Distribution according to Grade level



Materials and Research Instruments

Selection of Home-based Biology Experiments (HBEs)

Home-based biology experiments (HBEs) are tasks that make use of everyday household items, are related to standard learning competencies, and have been modified for the remote learning environment (Robledo, 2021). HBEs can be used to provide students with authentic learning experiences at home by using homes and kitchens as extensions of laboratories (Chu et al., 2021). All HBEs used in this study were practical guides developed and compiled by the lead researcher. These learning materials were adopted from different sources and modified for contextualisation and appropriateness. Validation was carried out by a group of science teachers from different institutions using an official evaluation checklist to ensure the alignment and appropriateness with the pupils' learning competencies and grade levels (Department of Education, 2008). These experiments were evaluated based on the six attributes of home-based biology experiments (Robledo, 2021). Overall, ten HBEs were described and used in the study (Appendix B).

Research Instruments

Each teacher-collaborator developed a 15-item parallel pre-test and post-tests aligned and appropriate for their scheduled topics and HBEs used in class. The 15-item perception questionnaire with open-ended questions was developed and validated by a group of science teachers and science coordinators (α =0.88). The 8-item self-efficacy questionnaire (α =0.79) was derived from the report of Bandura et al. (1996), and the 15-item engagement scale (α =0.92) was adopted from study by Wang et al. (2016) (Appendix C). Table 1 shows the scale that was used in interpreting the results. Moreover, this study collected teachers' and students' feedback using a series of focus group discussion and pupils' journals entries to determine the affordances and constraints of using HBEs. Google Jamboard was used in collecting the perceptions and feedback of the teachers and parents during the focus group discussion held via Zoom.

Table 1

4-Point Likert Scale for Interpretation

Verbal Interpretation	Scale
Strongly Agree	3.46-4.00
Agree	2.50-3.45
Disagree	1.50-2.49
Strongly Disagree	1.00-1.49

Note. (Source: Chua & Melor, 2020)

Data Gathering Procedure

Teacher's Orientation and Distribution of HBEs

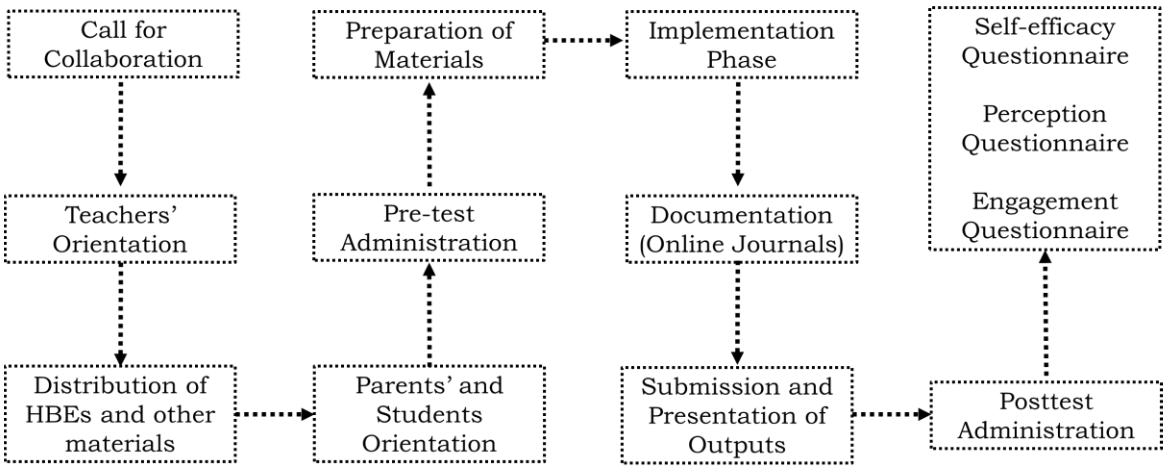
Two weeks after the call for collaboration, 16 teachers were invited for a one-hour virtual orientation session via Zoom. The researchers discussed the objectives of the project, the timeline of activities, expected outputs, and the duties and responsibilities of the collaborators. Moreover, researchers distributed the Guidelines for Work Area Selection via Google drive (Appendix D). In the latter part of the orientation session, time was allotted to address the questions and concerns of the teacher-collaborators. Six teachers raised their concerns about time management, and other school-related activities that would hamper their participation in the study. Only ten teachers pledged to participate in the study. The teacher-collaborators accomplished the data privacy declaration form, and informed consent form. Appropriate HBEs were distributed using Google drive. Facebook Group chat was created to support the teacher-collaborators before and during the implementation phase.

Implementation and Data Gathering Procedures

The implementation phase (Figure 6) was conducted from January to April 2021. Teacher-collaborators held a debriefing session with the parents to discuss their roles and ensure pupils' safety in implementing the HBEs. After the implementation of pre-test, the 10 HBEs were distributed among the pupils using Gmail, Google Drive, and other learning management systems. As a general rule, each student or group of students performed one home-based experiment. One week was given to the parents and pupils to gather and prepare all the materials needed for the experiment. Participants were encouraged to use recyclable or household materials that are readily available at home. In case of unavailability of materials, they were instructed to consult their science teachers to discuss their concerns.

Figure 6

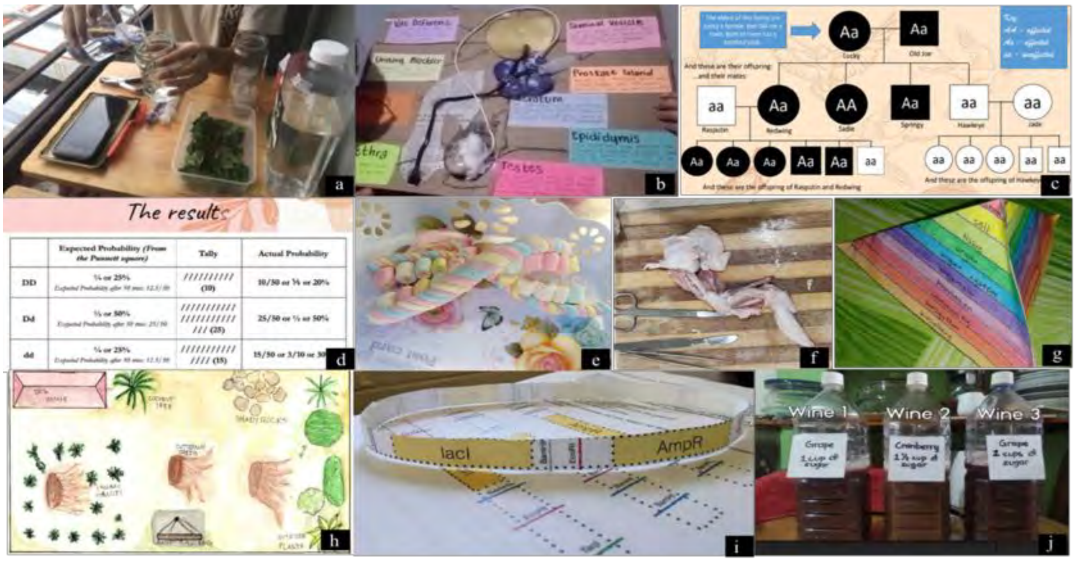
Implementation and Data Gathering Procedure



A pre-laboratory activity was conducted via Zoom to discuss the safety procedures and monitoring policies among the pupils. Parents and guardians were advised to monitor their child's progress constantly. During the implementation phase, pupils were encouraged to work to their own schedules. They were asked to document all procedures and report all incidents that may occur. The individual online journals were accomplished to narrate their experiences and challenges that they had encountered (Appendix H). Outputs and documentation were submitted via Google Drive and Gmail, as shown in Figure 7. The pupils presented their outputs in a during a combined lesson session and were evaluated using the HBE grading matrix (Appendix E). Teacher-collaborators administered the post-test and the survey questionnaires using Google forms with "Autoproctor" add-on. "Autoproctor" is an application that provides test recordings and trust ratings for each examination attempt using artificial intelligence and facial recognition technology (Socratease Inc, 2021). Virtual post-lab activity was conducted to discuss the results of pupils' performance.

Figure 7

Students' outputs in Home-based Biology Experiments (HBE)



*NOTE: a. **HBE1**- Photosynthesis-at-home Experiment; b. **HBE2**- 3D model of reproductive system; c. **HBE3**- Building Pedigree Activity; d. **HBE4**- Toss Your Genes Activity; e. **HBE5**- Edible DNA Activity; e. **HBE6**- Chicken wing dissection activity, f. **HBE7** -Foldable Biological Levels of Organization; g. **HBE8** -Backyard Biodiversity Activity; h. **HBE9** - Recombinant Paper Plasmid; i. **HBE10** - Yeast Balloons: Observing Cell Respiration*

The survey questionnaire was administered via Google forms and was accomplished during the post-evaluation session. All ten teacher-collaborators and parents (N=212) participated in the series of focus group discussion via Zoom. Google Jamboard was used to gather teachers' comments and responses to the following questions; *How did you use these HBEs in your class? What are you trying to solve or improve? What are your perceptions on the use of HBEs in terms of safety, feasibility, and appropriateness? What are the affordances and constraints that you experienced on the implementation of HBEs? How did you address the challenges you encountered on the implementation of HBE*s? The responses extracted from the Jamboard were transcribed and coded using Quirkos (See Appendices F and G).

Data Analysis

Inconsequential data were identified and filtered out using the data cleaning protocols of Biemer (2014) and AAPOR (2019. Eigtheen student-respondents were removed from the pool since most of their responses to Statement No. 11, "HBEs were fun and exciting" in the perception questionnaire were mostly 1s (Strongly Disagree), contradicting with their responses in Statement No. 15; "HBE makes me enjoy and feel enthusiastic about learning more about the topic", which is 4s and 5s (Agree and Strongly Agree, respectively). These are considered inconsistent or unreliable responses. Thus, excluding them from the data set is a good choice. Thus, only 818 or 97.8% are considered valid responses.

Results of the Shapiro-Wilk test revealed that the numerical data were not Normally distributed but were strongly skewed in favour of positive responses. Hence, non-parametric tests were used in analysing the data set. Descriptive statistics were used to describe the demographics of the respondents and mean scores for pre-test and post-tests, and the percentage frequency distribution of responses for the perceptions, self-efficacy, and engagement levels. Moreover, the normalised gain was also measured to quantify the degree of score differences (Hake, 1999). Levene's test revealed that the variances of the samples when grouped according to grade level, type of school, and home-based biology activity were not homogeneous. However, when the samples were grouped according to gender, their variances were homogeneous. The Wilcoxon-signed paired test and the Spearman Rho Rank Correlation test were used to determine the mean difference and correlation (Upadhyay et al., 2015). In addition, Mann-Whitney U and Kruskall-Wallis tests were used to determine the association factors and dependent variables. Thematic analysis was utilised to describe and interpret the feedback gathered from the teachers and students (Braun and Clarke, 2006).

Results

Knowledge Gains

As presented in Table 2, the results from the Wilcoxon Signed-Rank test showed that all groups exhibited a significant difference between pre-test and post test scores ($p<0.05$). Results revealed that pupils who had performed "Toss Your Gene Activity" (HBE4), "Edible DNA Model" (HBE5), "Backyard Biodiversity Activity" (HBE8), and "Yeast Balloons: Observing Cell Respiration" (HBE10) had a high level of learning gains with *g* values of 0.71, 0.85, 0.80 and 0.82 respectively. One of the pupils mentioned in the online journal that *"The edible DNA model helped me learn and appreciate the complex terms and structures of DNA. It also made the memorization much easier".* Conversely, Grade 11 students who performed HBE9 or "Recombinant Paper Plasmid" had the lowest learning gains (g=0.28). In one student's journal entry, it was noted that *"The activity was extra-challenging and hard to follow. The instructions were too technical and scientific.".* HBE1 "Photosynthesis at home Experiments", HBE2 "3D Model of Reproductive System", HBE3 "Building Pedigree Activity", HBE6 "Chicken Wing Dissection", and HBE7 "Foldable Biological Model of Organization" had a medium increase in learning gains with *g* values of 0.61, 0.48, 0.52, 0.65 and 0.66 respectively.

Overall, the pre- and post-tests scores showed there was medium increase in pupils' learning gains with a normalised gain of 0.68. This finding supports the study of Sshana & Abulubdeh (2020) where they found a positive correlation between practical science work and the academic attainment of most school students in science. Moreover, Bubbs & Jones (2020) found that pupils achieved more and performed better in home-based learning setup. They added that pupils were more creative in learning, have better progress, and greater student independence.

Students' Perceptions of Home-based Biology Experiments

Table 3 shows the percentage of pupil' perception on the use of HBEs in terms of general features, congruence with the lesson and learners' experiences. It can be gleaned that most of the pupil-participants responded "Agree" or "Strongly Agree" to all statements regarding their perceptions of the general features of HBEs. This suggests that the pupils generally have positive perceptions about the components, objectives, instructions, materials and equipment and safety in using HBEs. These perceptions were confirmed by the feedback such as *"My mum was supervising all throughout the activity, that's why I felt safe and secure".* It can also be noted that most of the responses were "Strongly Agree" to the statements about the congruence of HBE with the lessons. This indicates they found the HBEs relevant and appropriate to the topic, provided real-life application of the lesson and provided an opportunity for them to apply their learning. Furthermore, almost 60% found the HBEs to be fun and effective activities for learning the topic. The majority of the pupils responded "Strongly Agree" to the statement "HBE gives me the opportunity to modify and use alternative materials" which indicates that they were able to make changes to the materials of some of the experiments. These findings coincide with the study of Neves et al. (2017), Bishop et al. (2021), and Oktavia et al. (2020) where they found that high school students and college students had positive perceptions towards home-based practical activities. Participants in their studies made it clear that they preferred to carry out some exercises using take-home kits in the future, opening the door for positive long-term adjustments to the delivery of some practical activities outside of pandemic periods.

Table 2

Students' Pre-test and Post-test Scores for each Home-based Biology Experiment

Home-based Biology Experiments		N	Mean	SD	Wilcoxon test *T*	*Z*	*p*	*g*	Interpretation
HBE1	Pre	86	8.12	0.88	88.00	-4.56	0.01*	0.61	Medium
	Post	86	12.34	0.76					
HBE2	Pre	92	7.66	0.98	121.00	-6.78	0.00*	0.48	Medium
	Post	92	11.15	0.56					
HBE3	Pre	25	7.88	0.78	78.00	-8.76	0.00*	0.52	Medium
	Post	25	11.56	0.89					
HBE4	Pre	77	10.22	0.66	101.00	-6.45	0.04*	0.71	High
	Post	77	13.56	1.12					
HBE5	Pre	28	7.71	0.54	89.00	-5.56	0.033*	0.85	High
	Post	28	9.12	0.66					
HBE6	Pre	166	8.33	0.45	133.00	-8.67	0.012*	0.65	Medium
	Post	166	12.66	0.43					
HBE7	Pre	86	6.56	0.67	77.00	-9.55	0.013*	0.66	Medium
	Post	86	12.11	0.68					
HBE8	Pre	116	7.13	0.23	89.00	-6.55	0.014*	0.80	High
	Post	116	13.45	0.45					
HBE9	Pre	57	7.56	0.66	65.00	-3.88	0.044*	0.21	Low
	Post	57	12.33	0.43					
HBE10	Pre	85	10.11	0.56	88.00	-4.44	0.038*	0.82	High
	Post	85	14.12	0.77					
Overall	Pre	818	9.65	0.89	119.00	-4.56	0.045*	0.68	Medium
	Post	818	13.56	0.78					

Note: *p <0.05, **p<0.01 z= Wilcoxon signed rank test, N= total number of students, g=normalized gain -scale: ("High" g>0.70) ("Medium" 0.3<g<0.7) ("Low" g<0.3) (Hake, 1999)

Students' Self-efficacy in the context of Home-based Biology Experiments

Table 4 shows the percentage distribution of pupils' responses on the effects of HBEs on their self-efficacy. Most responded "Agree" and "Strongly Agree" to all pertinent statements. This implies that they perceived themselves as being efficacious in performing the HBEs in the sense that they were motivated, optimistic and independent, and were confident when presented with difficult tasks. These findings were reflected in their journal entries such as *"I was confident to perform the experiment because I was at home and my parents were there to ensure my safety"*. It was noted that 4 out of the 8 statements showed a median response of "Strongly Agree", and the other half for "Agree". In the study of Fitriani et al. (2017), results showed that pupils had moderate level of self-efficacy after doing the assigned practical activity in biology. They also noted that some pupils exhibited a low level of self-efficacy which adversely affected their academic performance. These findings are similar to the study by Juan et al. (2018) which demonstrated that there was a positive relationship between self-efficacy and science achievement and suggested a need to also focus on noncognitive aspects to improve science achievement. Moreover, the study of Rusmansyah et al. (2021) showed that there was a significant increase in students' self-efficacy and science process skills in doing practical activities at-home assisted by Google Classroom and Google Meet applications.

Table 3

Students' Perceptions on the use of Home-based Biology Experiments

Students' Perceptions	Frequency Distribution (%)				
	SD	D	A	SA	M ± SD
General Features					
1. Objectives were stated and attainable.	0.37	2.93	36.80	59.90	3.57 ± 0.76
2. Materials and tools were readily available and affordable.	1.34	8.19	37.04	53.42	3.44 ± 1.22
3. Home-based biology experiment was safe to perform.	0.98	4.65	30.56	63.81	3.58 ± 0.66
4. Instructions and procedures were clear and easy to follow.	0.61	5.26	32.89	61.25	3.55 ± 0.89
5. Materials were changeable and adaptable.	0.98	7.33	40.10	51.59	3.43 ± 0.43
Lesson Congruency					
6. Directly applies what was taught in the lesson.	0.61	3.55	34.60	61.25	3.57 ± 0.99
7. Shows coherence and unity with the topic discussed.	0.61	3.55	37.53	58.31	3.54 ± 0.54
8. Provides real-life application of the lesson.	0.73	5.01	35.09	59.17	3.53 ± 0.79
9. Provides good hands-on activity for the topic.	0.73	3.18	33.01	63.08	3.59 ± 0.89
10. Relates with the processes and concepts taught in the lesson.	0.12	3.67	34.23	61.98	3.58 ± 0.78
Students' Experiences					
11. HBE was fun.	1.10	6.72	37.41	54.77	3.47 ± 0.55
12. HBE allows me to use alternative materials.	0.49	4.16	36.43	58.92	3.54 ± 0.98
13. HBE was challenging.	1.83	15.16	35.21	47.80	3.31 ± 0.76
14. HBE was an effective way to learn about the assigned topics.	0.49	3.30	37.41	58.80	3.55 ± 0.56
15. HBE makes me feel enthusiastic about learning about the topic.	1.10	6.36	36.80	55.75	3.48 ± 0.76
Overall	0.86	4.50	43.56	51.94	3.56 ± 0.77

Notes: SD=strongly disagree, D=disagree, A=agree, SA=strongly agree, M= mean, ±= standard deviation

Table 4

Students' Self-efficacy after using Home-based Biology Experiments

	Frequency Distribution (%)					
Students' Self-efficacy	SD	D	A	SA	M	± SD
1. I will be able to finish most of the HBEs that were assigned to me.	0.24	3.42	44.50	51.83	3.48	0.66
2. When facing difficult HBE, I am confident that I will accomplish them.	0.61	6.11	45.35	47.92	3.41	0.54
3. In doing HBEs, I think that I can obtain outcomes that are important to me.	0.12	2.32	43.89	53.67	3.51	1.02
4. I believe I can succeed at most of the HBEs to which I set my mind.	0.24	5.01	42.30	52.44	3.47	0.88
5. I will be able to overcome many challenges in doing HBEs successfully.	0.12	5.38	40.59	53.91	3.48	0.78
6. I am confident that I can perform effectively on the HBEs assigned to me.	0.00	12.1	46.70	41.20	3.29	0.76
7. Compared to others, I can do most of the HBEs very well.	2.08	18.0	55.38	24.45	3.04	0.64
8. Even when the HBEs are tough, I can perform quite well.	0.61	9.29	51.10	39.00	3.29	0.43
Overall	0.53	3.45	43.76	52.79	3.36	0.71

Note: SD=strongly disagree, D=disagree, A=agree, SA=strongly agree, M= mean, ± SD = standard deviation

Students' Engagement with Home-based Biology Experiments

In this study, students' engagement was divided into three components: cognitive, behavioural, and emotional engagements. Table 5 shows that most of the pupils responded "Agree" or "Strongly Agree" to the statements about cognitive engagement. This implies that they used their cognitive skills while doing the assigned HBEs. These skills may include problem solving skills, reflection, and observation skills. Statement No. 3 - *"I tried to understand my mistakes when I got something wrong*" - drew the highest percentage (66.6%) which suggests that most pupils were able to reflect on their performance and identify their mistakes as they performed the activity. Conversely, Statement No. 5 "I do more than or beyond the required activity" had the highest number of pupils who responded "Disagree" (21.27%). This insinuates that student that they lacked the confidence to extend the work. Otherwise, they appeared satisfied with the results of their work.

Most of the pupils responded "Agree" or "Disagree" to the statements about behavioural and emotional engagement. They could accordingly remain focused, complete the assigned tasks, and continue working even though the tasks were challenging. However, it was noted that 12.4% (N=818) of the pupils responded "Disagree" on Statement No. 8 "I completed the assigned activity on time" indicating that they were not able to submit their output on time. These results were verified from the teachers' feedback, e.g. *"My students were not able to submit on time because of poor internet connection,* *distractions at home, and difficulty of tasks assigned"*. Furthermore, the majority of the pupils were also emotionally engaged during the implementation of HBEs i.e. they enjoyed the activity. These findings coincide with the study of Hampden-Thompson & Bennett (2013), where they found students' motivation and engagement in science class improved significantly whenever they were exposed to practical learning activities. They also added that there are relationships among students' motivation for science, engagements in science, and future orientation to science and the frequency with which various teaching and learning activities occur in the class.

Table 5

Students' Engagement with Home-based Biology Experiments

Students' Engagements	Frequency Distribution (%)				Md	±SD
	SD	D	A	SA		
Cognitive Engagements						
1. I think about different ways to solve a problem in the HBEs.	0.73	4.40	43.64	51.22	3.46	0.43
2. I try to connect my learning from the HBEs to things I have learned before	0.24	3.42	38.51	57.82	3.54	0.22
3. I try to understand my mistakes when I get something wrong in HBE.	0.24	1.22	31.91	66.63	3.65	0.65
4. I go through the work for the HBE and make sure that it's right	0.24	3.18	36.67	59.90	3.56	0.87
5. I do more than or beyond the required outputs in the HBE.	2.81	21.27	49.63	26.28	3.02	0.65
Behavioral Engagements						
6. I stay focused when performing the HBE.	0.73	9.78	47.07	42.42	3.32	0.77
7. I keep trying even if the HBE is hard.	0.37	3.30	37.16	59.17	3.56	0.88
8. I completed the assigned HBE on time.	1.59	12.35	35.94	50.12	3.36	0.89
9. I put effort into doing the HBE.	0.12	2.81	33.86	63.20	3.60	0.54
10. If I don't understand the HBE, I don't give up right away	0.24	3.18	37.16	59.41	3.56	0.78
Emotional Engagements						
11. I look forward to more HBEs.	1.59	12.35	46.94	39.12	3.25	0.78
12. I feel satisfied when I am doing home-based experiments.	0.61	10.02	50.12	39.24	3.29	0.67
13. I enjoy learning new things about home-based biology experiments.	0.37	5.38	40.71	53.55	3.48	0.89
14. I think that a home-based biology experiment is fun and engaging.	0.98	5.75	40.34	52.93	3.46	0.65
15. I care about learning the concept behind the HBEs.	0.98	3.42	40.22	55.38	3.51	0.76
Overall	0.88	7.89	41.34	50.77	3.45	0.88

Note: SD=strongly disagree, D=disagree, A=agree, SA=strongly agree, M=mean, ± SD = standard deviation

Responses When Grouped According to Demographics

As presented in Table 6, there is a significant difference in the students' knowledge gains by grade level and HBE used. This indicates that test scores may vary according to grade level and experiment that was being used. These findings were also evident in Table 3. Perceived levels of engagements were found to be affected by their grade level and type of HBE. Overall, this findings show that grade level and type of HBEs consistently affect all the independent variables in the study. Similarly, Freeman et al. (2014) discovered regardless of the type of school, active learning through practical activity significantly enhanced students' achievements as indicated by test scores and engagement indicators On the other hand, these findings oppose the study of Hu et al. (2022), where they found that there were varying levels of self-efficacy for girls and boys across different grade levels. They discovered that for Levels 1 and 4, most girls had stronger science self-efficacy than boys, however for the intermediate levels, Levels 2 and 3, most boys had higher science self-efficacy than girls.

Table 6

Tests of Mean Difference among Independent Variables

Dependent Variables	Demographics				Mn	SD
	Grade Level[a]	Gender[b]	Type of School[b]	HBE[a]		
Knowledge gains	S	NS	NS	S	3.67	0.56
Students' Perceptions	S	S	NS	S	3.46	0.50
Students' Self-efficacy	S	NS	NS	S	3.32	0.56
Students' Engagements	S	NS	NS	S	3.39	0.52

Note: S – Significant, NS – Not Significant, [a]Kruskal-Wallis Test, [b] Mann-Whitney Test

Correlations Among the Knowledge gains, Perceptions, Self-Efficacy and Engagement

Table 7 shows the results of the Spearman Rho test of correlation among the four independent variables. Knowledge gains were correlated with perceptions of HBE, self-efficacy and perceived levels of engagement ($r=0.712$, $r=0.784$ and $r=0.655$, respectively). This could mean that their insights on the features of HBE, the objectives and overall experience, motivation, and behaviours might have strong relationship and connection to their academic performance. Perception ratings have strong correlations with self-efficacy and engagement levels ($rs=0.625$, $rs=0.744$, $p<0.01$). This suggests that their performance during the implementation of the HBEs were connected to their insights and perceptions on HBEs. Accordingly, results showed that all independent variables appear to correlate strongly with one other. These findings coincide with the study of Safdar et al. (2021), where they highlighted the direct relationship between self-efficacy and knowledge gain. In the quasi-experiment of Phoosuwan and Lundberg (2020), it was found that pupils' experiences in class are highly related to their knowledge gain, having a positive attitude, and having confidence and ability to perform given tasks. Likewise, Azila-Ggbettor et al. (2021) demonstrated strong evidence of linear relationships among pupils' achievements, motivation, attitude, and self-efficacy that positively contributed to peer and individual engagement in class.

Table 7

Correlation among the Four Dependent Variables

Variables	Knowledge gains	Perceptions	Self-efficacy	Engagement
Knowledge gains	1.00	0.712*	0.784*	0.655*
Perceptions	0.712*	1.00	0.625*	0.744*
Self-efficacy	0.784*	0.625*	1.00	0.782*
Engagements	0.655*	0.744*	0.782*	1.00

Affordances and Constraints on the Use of Home-based Biology Experiments

Table 8 shows the thematic analysis based on the open-ended questions and transcripts from the series of focus group discussion. Teachers' and pupils' feedback were analysed and generated two general themes and 10 sub-themes. The first general theme was the affordance of using HBEs which includes safety, feasibility, appropriateness, and independent learning. Teachers mentioned that HBEs were safe to do at home because pupils were closely monitored and supervised by their parents and guardians. This coincides with pupils' feedback saying that they were learning while still being safe from the virus. Some parents and pupils also appreciated the feasibility of HBEs since the materials were affordable and readily available, and they found it appropriate for their lessons. Moreover, pupils considered the HBEs as effective teaching approach because they had the opportunity to reflect on their performance and learn independently.

Table 8

Exerpts from Teachers', Pupils', and Parents' Feedback on the Affordance and Constraints of using Home-based Biology Experiments (ad literatum)

	Affordances	Constraints
Teachers' Feedback (N=10)	Safety (n=8) "The materials are safe. The students' safety is not compromised. HBEs allowed the students to work independently without facing risks. They do not need to go outside their houses." Feasibility and Appropriateness (n=7) "Students are able to learn without spending too much, thus helping them to develop their creativity. HBEs contains supporting details unlocking the main concept of the topics"	Expenses (n=7) "I still have students who complain about expenses and details about the ratio of materials in yeast and juices." Student interaction (n=6) "Since my students were studying from home, there was less interaction among them, if they have some questions while doing the activity"

Students' Feedback (N=818)	Independent learning (n=618) "We can learn on our own, see our mistakes, and find solutions by ourselves without the help of our teacher." Learning Material (n=559) "Home-based biology experiments were an effective way to learn the topics. Learning biology at home is the best because I don't have to go outside when there's a pandemic and it made me learn a lot. They allow students to expand their knowledge in the field of science and enjoy the world around them."	Availability of Materials (n=121) "Some materials are not available in our place and the other market is quite far from our house, but we managed to find the appropriate materials." Time management (n=118) "I struggled with scheduling. How to finish the home-based biology experiments in time. Sometimes I don't have time to do the experiment because of the lots of assignments.
Parents' Feedback (N=212)	Affordability (n= 181) "Experiments were useful and affordable. We used the materials available at home." Learning Experience (n=202) "My child really enjoyed the HBE, and I saw he become more excited about the subject."	Time Management (n=196) "It hard for us to monitor the activities of my child at home, because I am working fulltime."

These findings were evident in the significant improvements on knowledge gains, self-efficacy, and perceived levels of engagement. These findings are consistent with those of Yıldız-Feyzioğlu et al., (2021), in which students learn best and most efficiently when they were guided by the teachers or parents. Dhanapal and Shan (2014) found that well-developed practical activities in science significantly affect the learning performance of the pupils. According to their findings, several pupils performed better because they learned and remembered more effectively through hands-on experiments. When students learned through hands-on experiments, they demonstrated a higher level of participation and intrinsic drive. Although these relevant published works were conducted in in-person classes, their findings might still apply in virtual settings. The researchers believe Kolb's experiential theory is particularly helpful when doing hands-on experiments since it assures pupils effectively understand facts given.

With regard to the flipside of the coin, some teachers, parents and pupils mentioned the constraints that they had experienced in the implementation of HBEs. The primary restriction that they had encountered was the unavailability of some materials. Some had difficulty gathering materials owing to COVID-19 travel restrictions. They also stated that some materials were expensive, and they had to look for alternatives. Some teachers noted that there was less interaction among the pupils because they were all studying from home. Some pupils reported that they had to repeat the experiment several times because they could not understand the instructions and procedures. They also were not able to submit on time due to distractions at home and poor time management. These findings support the studies of Mona et al. (2022), and Fostervold et al. (2022) who reported that pupil stress were increased by both their procrastination and independent study time, whereas remote teaching might reduced procrastination at a moderate level.

Discussion

The study was designed to determine the effects of home-based biology experiments on pupils' knowledge gains, self-efficacy, and perceived levels of engagement. Findings revealed significant increase in knowledge gains after doing the HBEs and this was confirmed by their feedback on the effectiveness of HBEs. This claim is consistent with the study of Lowe et al. (2013), wherein they mentioned that authentic and experiential learning activities could significantly improve learners' academic performance. Results also showed that Grade levels and HBEs were factors that also affect knowledge gains. Pupils' level of comprehension and prior knowledge about the topic were important factors in students' academic performance in distance learning. Students at the higher grade level tend to achieve more and perform well in a remote learning setup. These findings coincide with a study about students' schema, level of maturity, and study habits that positively affect students' understanding and academic achievements (Zimmerman, 1990). Mok (2020) argued that to strengthen the conceptual understanding in learning science, there should be real-life application of the lesson. This concept has been applied in the implementation of HBEs, that each lesson has a corresponding home-based practical activity to provide authentic learning experience at home.

Pupil perceptions of the HBEs showed that the components had been well-crafted and organised; the objectives were clearly stated and attainable, and most of the pupils appear to have had a highly positive experience with the use of HBEs. Pupil satisfaction has been a determining factor in learners' academic progress ; those who find the activity more engaging and satisfying tend to be more active and enthusiastic in their virtual class The appropriateness and attainability of learning objectives could also affect students' performance and attitudes towards the subject. This claim was confirmed in the study of Hazari (2014), which showed that pupils' perceptions on learning activities greatly influence their academic performance both in in-person and remote class. In addition, this study identified that grade level, gender, and HBEs were determining factors that may affect students' perceptions. Students from higher grade levels (Grade 10 and 11) have a greater sense of appreciation of the components and effectiveness of learning activities. This study also revealed that gender difference could affect students' perception where female students are more appreciative than male students, while male students are more inclined to practical activities than the females, which support the study of Hensen and Barbera (2018. Other studies have proven that age, grade level, and gender significantly affect academic performance of students in learning science (Voyles et al. 2011; Shirazi, 2017; Siddiquah, 2019).

Self-efficacy and perceived levels of engagement were also determined in the study to establish the effectiveness of HBEs. Results showed students' self-efficacy and perceived level of engagement were significantly improved after using the HBEs. Engagement was evident through being able to think critically, reflect on their practice and identify their mistakes in the process (Beri and Stanikzai, 2019). Moreover, pupils exhibited positive emotions when they performed the HBEs. This suggests that even though those experiments were conducted at home, pupils might be able to manifest positive attitudes and outlook in science-related activities. In the study of Fencl and Scheel (2005), it was confirmed that pupil engagement was significantly higher when they performed authentic hands-on learning activities in class rather than doing virtual experiments or computer simulations. This study also revealed that grade level and HBEs could influence self-efficacy and engagement levels. Findings have shown that all four independent variables exhibited strong correlations with one another ($p<0.01$). This suggests that pupils' perceptions of HBEs have a strong positive relationship on their self-efficacy. Those who found the experiments interesting and engaging tend to become more motivated to perform and accomplish the assigned task, thus expanding their understanding and gaining more learning in class, consistent with Muilenburg et. al, 2005. Ketelhut (2007) explained that learners' confidence in doing activities and exploring new things is essential in developing their scientific inquiry skills . Hayat et al (2020) added that students' self-efficacy influences their learning-related emotions and metacognitive learning practices, which in turn influence their academic success. Furthermore, learning-related emotions have an impact on metacognitive learning techniques, which in turn moderate the effect of emotions on academic achievement.

HBEs were found to be effective as learning strategies based on teachers' and learners' feedback. Two general themes were generated; (1) on the plus side of the ledger, participants believed HBEs were safe to perform at home, feasible and appropriate, promote independent learning and reinforce conceptual understanding, consistent with Ma and Nickerson (2006) who surmised that practical learning activities enhance learning independence and learning gains. (2) On the negative side of the ledger, participants mentioned the unavailability of materials, less pupil interaction, and poor time management. These findings coincide with the study of Maltese and Tai (2010), which revealed that pupils lose their interest in a learning activity when they cannot manage their time properly. Moreover, these claims were supported in the study of Kanli and Ilican (2020), they discussed that learners' diversity and different learning styles, and time-management behaviours strongly affect their academic performance.

Conclusions

Looking back into the study, HBEs were found to be effective in improving students' knowledge gains, perceptions, self-efficacy, and perceived levels of engagement. Other factors such as grade level, gender, and HBEs were also found to influence students' responses. Teachers should consider these factors in select or develop HBEs. Although this study did not assess the practical skills of the learners, it adds to the growing literature that focuses on effectiveness of home-based biology experiments in distance learning. Based on the results of the study, it is recommended for future researchers to focus more on the appropriateness of learning activities, feasibility of learning objectives and inclusion of parents' perspectives when designing home-based biology experiments.

Ethical Considerations

Data privacy and ethical considerations were assured throughout the conduct of the study. Teacher- and pupil participants were given a data privacy declaration form and informed consent form via Google forms and were asked to volunteer for the study understanding all the rights of withdrawal and refusal. No data were sought to exhibit participants' direct identity such as names, contact numbers, addresses, or other personal information. All responses were treated with utmost discretion and confidentiality.

Declaration of Interests

The authors of this study confirm that this manuscript has not been previously published and is not currently under consideration for publication elsewhere. Additionally, we have no conflicts of interest to disclose.

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Appendix A

Roles of the Parents and Guardians in the Implementation of HBEs

PARENT-TEACHER AGREEMENT FORM

I am <insert name>. the parent of <insert name of the child>, understand the importance of experimentation as an essential component of scientific learning. Thus, I voluntarily assume the role of "Home-based Laboratory Supervisor," and I understand the following obligations.

Preparation

I will …

- assist my child in the preparation of the working area or any designated place for the experiment.
- never allow my child to perform unauthorized experiments.
- ensure that my child was appropriately dressed before doing any investigation.
- Observe the following protocols: tie back long hair, do not wear long sleeves and dress, as they tend to get messy, wear lab coats or aprons (if necessary), wear safety goggles (if required), wear gloves when using chemicals that irritate or can be absorbed through the skin.

Implementation

I will…

- ensure that my child will never taste or "sniff" chemicals.
- keep combustibles away from open flames or in the working area of my child
- ensure that the heat source is turned off when not in use (if applicable).

I will report all accidents and spills to the adviser or science teacher immediately in case of accidents. If I cannot fulfill the roles mentioned above, the experiment will be conducted synchronously under the supervision of the science teacher. I will also voluntarily participate in the focus group discussion to share my perceptions and feedback on the implementation of HBEs.

____

Signature Over Printed Name of the Parent/Guardian

Appendix B

List of Home-based Biology Experiments used in the study

(HBE_#) Home-based Biology Experiment	Description	Grade level/ Topic	Source
HBE1 Photosynthesis-at-home Experiment	In this experiment, students studied the photosynthesis process in leaf disks by observing how the leaves release tiny oxygen bubbles. Length: 2 hours	Grade 9/ Ecosystems Photosynthesis	Clear Community Scholar Organization (2021) Link: https://www.clearwaycommunitysolar.com/blog/science-center-home-experiments-for-kids/learn-how-photosynthesis-creates-a-natural-chemical-reaction/
HBE2 3D Model of Reproductive System	Students created a model of the reproductive system using household tools and recyclable materials. The models were presented and discussed in a synchronous session. Length: 2 hours	Grade 10/ Functions of Reproductive System	Researcher-made Activity
HBE3 Building Pedigree Activity	Using the letters from a biologist, the students developed a pedigree presenting the traits and features of the animal described in the notes. Length: 2 hours	Grade 11/ Genetics Mendel's Laws of Inheritance Sex Linkage	Iowa Institute of Human Genetics Link: https://medicine.uiowa.edu/humangenetics/
HBE4 Toss Your Genes Activity	This activity simulates a monohybrid cross by using a simple coin toss. Length: 2 hours	Grade 11/ Genetics	Southern Biological (2021) Link: https://www.southernbiological.com/coin-toss-genetics/
HBE5 Edible DNA Model	Students designed a DNA model using edible materials such as candies, mallows, and many more. Their outputs were presented in synchronous class sessions. Length: 2 hours	Grade 8/10 Genetics Inheritance	Researcher-made Activity

HBE6 Chicken Wing Dissection Activity	This activity utilized chicken wing dissection as the model for the muscles and bones of the human limbs. Length: 2 hours	Grade 5 Human Body Systems	EL Education (2021) Link: https://eleducation.org/resources/life-science-chicken-wing-dissection
HBE7 Foldable Biological Levels of Organization	In this activity, students observed that biological organization is a hierarchical system of classification using a foldable framework. Length: 2 hours	Grade 7 Levels of Biological Organization	Research-made Activity
HBE8 Backyard Biodiversity Experiment	Students conducted a mini-survey and species collection in their backyard to study species diversity. They also developed a species map which they presented in a synchronous class. Length: 2 hours	Grade 7 Interactions Among Living Things	Jessica Shea, National Geographic (2019) Link: https://www.nationalgeographic.org/activity/backyard-bioblitz/
HBE9 Recombinant Paper Plasmid	This activity simulates genetic engineering at home by identifying a trait of interest, isolating that inserting genetic trait using the paper model. Length: 2 hours	Grade 11 Recombinant DNA Technology	Jenkins, C. L. (1987). Recombinant Paper Plasmids. *The Science Teacher*, *54*(4), 44–48. http://www.jstor.org/stable/24139444
HBE10 Yeast Balloons: Observing Cell Respiration	This experiment demonstrates the cellular respiration of yeasts. Yeast uses specific enzymes to metabolize complex sugars—like ordinary household sugar—into energy. This process releases carbon dioxide gas which inflates the balloon. Length: 2 hours	Grade 11 Cell Respiration Fermentation	Blow Up a Balloon With Yeast. Science Bob (2013) http://www.sciencebob.com/experiments/yeast.php

Note: *Adapted from K to12 Basic Education Curriculum Guide (DepEd, 2016).

Appendix C

Students' Perception, Self-efficacy, and Engagements Questionnaire

Students' Perception, Self-Efficacy, & Engagement	Scale SD	D	A	SA
Part I. Students' Perception				
General Features of HBE				
1. Objectives were stated and attainable.	O	O	O	O
2. Materials and tools were readily available and affordable.	O	O	O	O
3. Home-based biology experiment was safe to perform.	O	O	O	O
4. Instructions and procedures were clear and easy to follow.	O	O	O	O
5. Materials were changeable and adaptable.	O	O	O	O
Congruency with Lesson. (HBE…)				
6. Directly applies what was taught in the lesson.	O	O	O	O
7. Shows coherence and unity with the topic discussed.	O	O	O	O
8. Provides real-life application of the lesson.	O	O	O	O
9. Provides good hands-on activity for the topic.	O	O	O	O
10. Relates with the processes and concepts taught in the lesson.	O	O	O	O
Students' Experience				
11. HBE was fun.	O	O	O	O
12. HBE allows me to use alternative materials.	O	O	O	O
13. HBE was challenging.	O	O	O	O
14. HBE was an effective way to learn about the assigned topics.	O	O	O	O
15. HBE makes me feel enthusiastic about learning about the topic.	O	O	O	O
Part II. Students' Self-Efficacy				
1. I will be able to finish most of the HBEs that were assigned to me.	O	O	O	O
2. When facing difficult HBE, I am confident that I will accomplish them.	O	O	O	O
3. In doing HBEs, I think that I can obtain outcomes that are important to me.	O	O	O	O
4. I believe I can succeed at most of the HBEs to which I set my mind.	O	O	O	O
5. I will be able to overcome many challenges in doing HBEs successfully.	O	O	O	O
6. I am confident that I can perform effectively on the HBEs assigned to me.	O	O	O	O
7. Compared to others, I can do most of the HBEs very well.	O	O	O	O
8. Even when the HBEs are tough, I can perform quite well.	O	O	O	O
Part III. Students' Engagement				
1. I think about different ways to solve a problem in the HBEs.	O	O	O	O
2. I try to connect my learning from the HBEs to things I have learned before	O	O	O	O
3. I try to understand my mistakes when I get something wrong in HBE.	O	O	O	O
4. I go through the work for the HBE and make sure that it's right	O	O	O	O
5. I do more than or beyond the required outputs in the HBE.	O	O	O	O
6. I stay focused when performing the HBE.	O	O	O	O
7. I keep trying even if the HBE is hard.	O	O	O	O
8. I completed the assigned HBE on time.	O	O	O	O
9. I put effort into doing the HBE.	O	O	O	O
10. If I don't understand the HBE, I don't give up right away	O	O	O	O

11. I look forward to more HBEs.	O	O	O	O
12. I feel satisfied when I am doing home-based experiments.	O	O	O	O
13. I enjoy learning new things about home-based biology experiments.	O	O	O	O
14. I think that a home-based biology experiment is fun and engaging.	O	O	O	O
15. I care about learning the concept behind the HBEs.	O	O	O	O

Appendix D

Guidelines for Work Area Selection (For the parents and students)

1. Although the hazards are modest and manageable for you and for your furnishings, counters, and floors, the same may not always be stated. Please ensure that sinks and first aid kits are accessible.

2. If your area is properly lighted, well-ventilated, or similar, this's the best place to perform the messier work in a biology laboratory course.

3. It is a bad decision to store science equipment, chemicals, and other associated products in the food preparation and consumption area and only use these goods during the lab sessions in the kitchen. Store them elsewhere, safe from pets and children.

4. Protect kitchen table or other work surfaces from spill or mess. Decent protection is an inexpensive plastic cover. Cover the tableware with newspaper, towels or something else that absorbs waste and always has a convenient roll of paper towels.

Appendix E

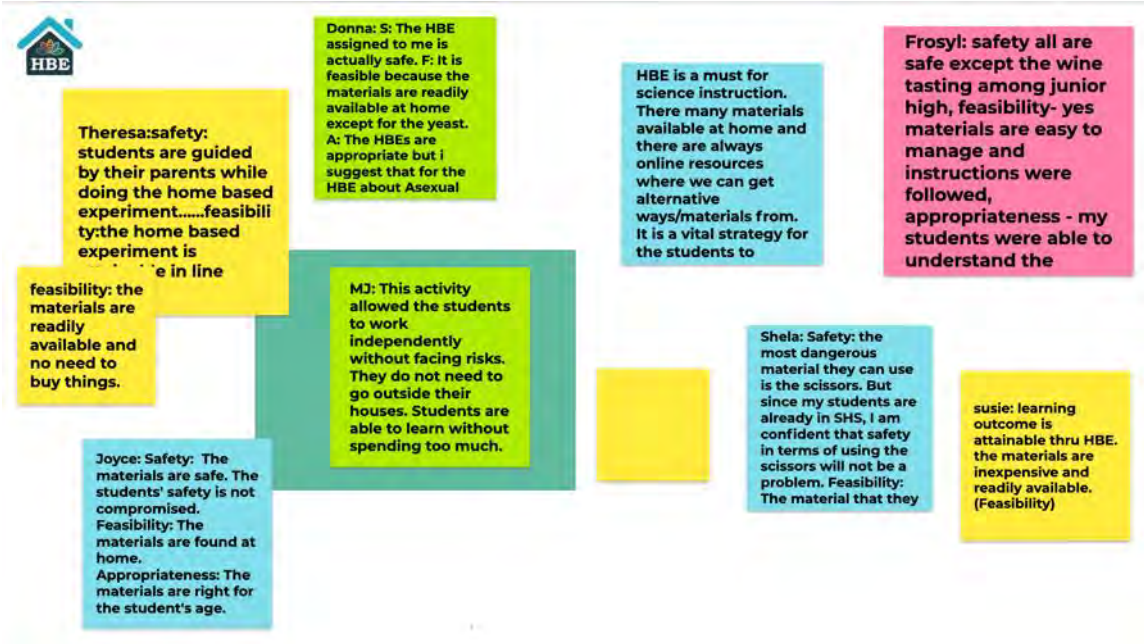
Grading Rubrics for Home-based Biology Experiment

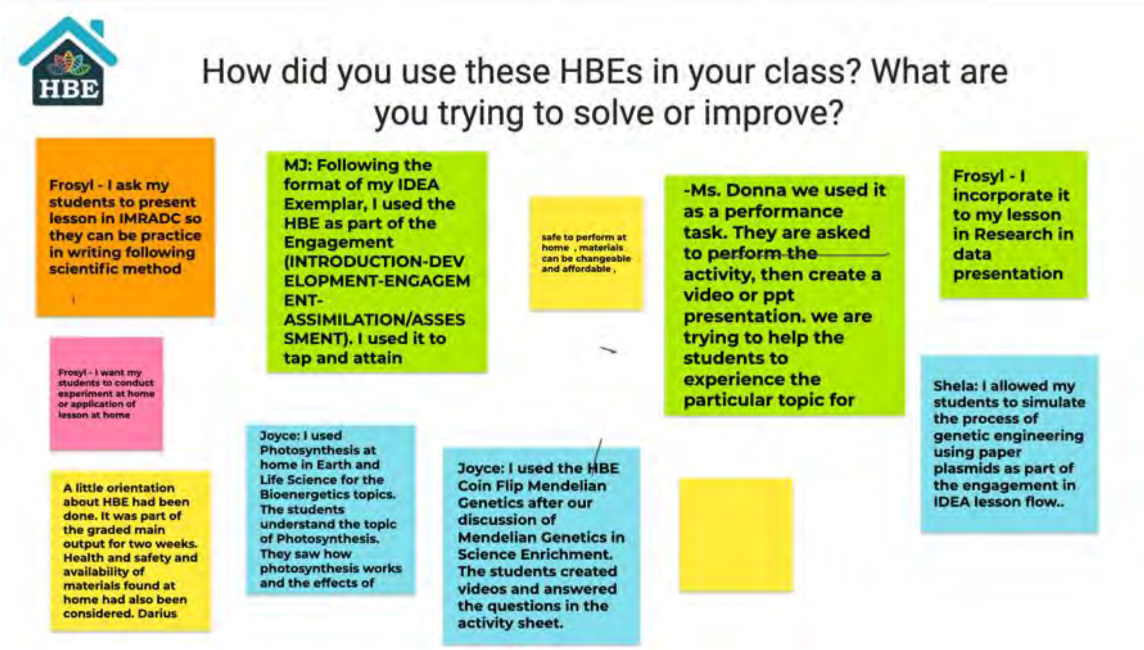
CATEGORY	Exemplary (4)	Satisfactory (3)	Unsatisfactory (2)	Poor (1)
Content	Shows a full understanding of the topic.	Shows a good understanding of the topic.	Shows a good understanding of parts of the topic.	Does not seem to understand the topic very well.
Comprehension	Student is able to accurately answer almost all questions posed by classmates about the topic.	Student is able to accurately answer most questions posed by classmates about the topic.	Student is able to accurately answer a few questions posed by classmates about the topic.	Student is unable to accurately answer questions posed by classmates about the topic.
Preparedness	Student is completely prepared and has obviously rehearsed.	Student seems pretty prepared but might have needed a couple more rehearsals.	The student is somewhat prepared, but it is clear that rehearsal was lacking.	Student does not seem at all prepared to present.
Collaboration with Peers	Almost always listens to, shares with, and supports the efforts of others in the group. Tries to keep people working well together.	Usually listens to, shares with, and supports the efforts of others in the group. Does not cause "waves" in the group.	Often listens to, shares with, and supports the efforts of others in the group but sometimes is not a good team member.	Rarely listens to, shares with, and supports the efforts of others in the group. Often is not a good team member.
Listens to Other Presentations	Listens intently. Does not make distracting noises or movements.	Listens intently but has one distracting noise or movement.	Sometimes does not appear to be listening but is not distracting.	Sometimes does not appear to be listening and has distracting noises or movements.
Stage Presence	Speaks clearly and distinctly all (100-95%) the time, and mispronounces no words. Volume is loud enough to be heard by all audience members throughout the presentation.	Speaks clearly and distinctly all (100-95%) the time, but mispronounces one word. Volume is loud enough to be heard by all audience members at least 90% of the time.	Speaks clearly and distinctly most (94-85%) of the time. Mispronounces no more than one word. Volume is loud enough to be heard by all audience members at least 80% of the time.	Often mumbles or can not be understood OR mispronounces more than one word. Volume often too soft to be heard by all audience members.
Posture and Eye Contact	Stands up straight, looks relaxed and confident. Establishes eye contact with everyone in the room during the presentation.	Stands up straight and establishes eye contact with everyone in the room during the presentation.	Sometimes stands up straight and establishes eye contact.	Slouches and/or does not look at people during the presentation.
Visual Aid	Student uses several visual aids (could include costume) that show considerable work/creativity and which make the presentation better.	Student uses 1 several visual aid that shows considerable work/creativity and which makes the presentation better.	Student uses 1 visual aid which makes the presentation better.	The student uses no visual aids OR the visual aids chosen (could include attire) detract from the presentation.

Adopted from: Stellmack, M.A., Konheim-Kalkstein, Y.L., Manor, J.E., Massey, A.R., & Schmitz, J.A. (2009). An Assessment of Reliability and Validity of a Rubric for Grading APA-Style Introductions. The teaching of Psychology, 36, 102 - 107.

Appendix F

Sample of Participants' Responses in the Focus Group Discussion (Google Jamboard)



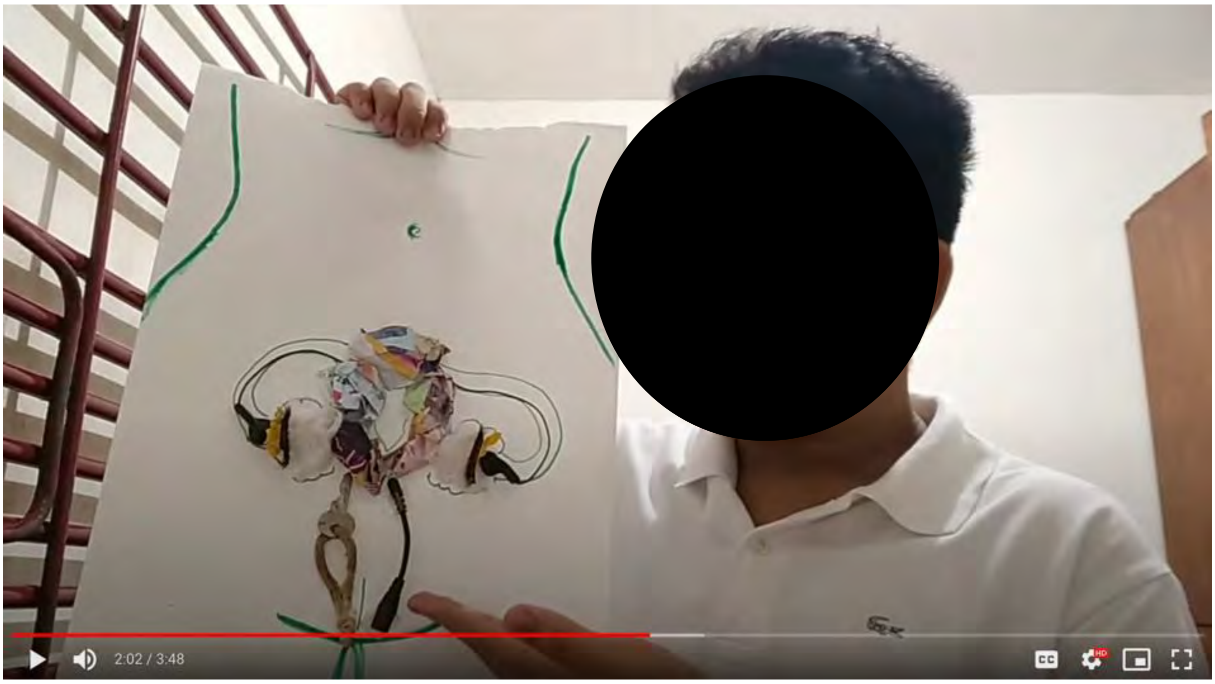


Appendix G

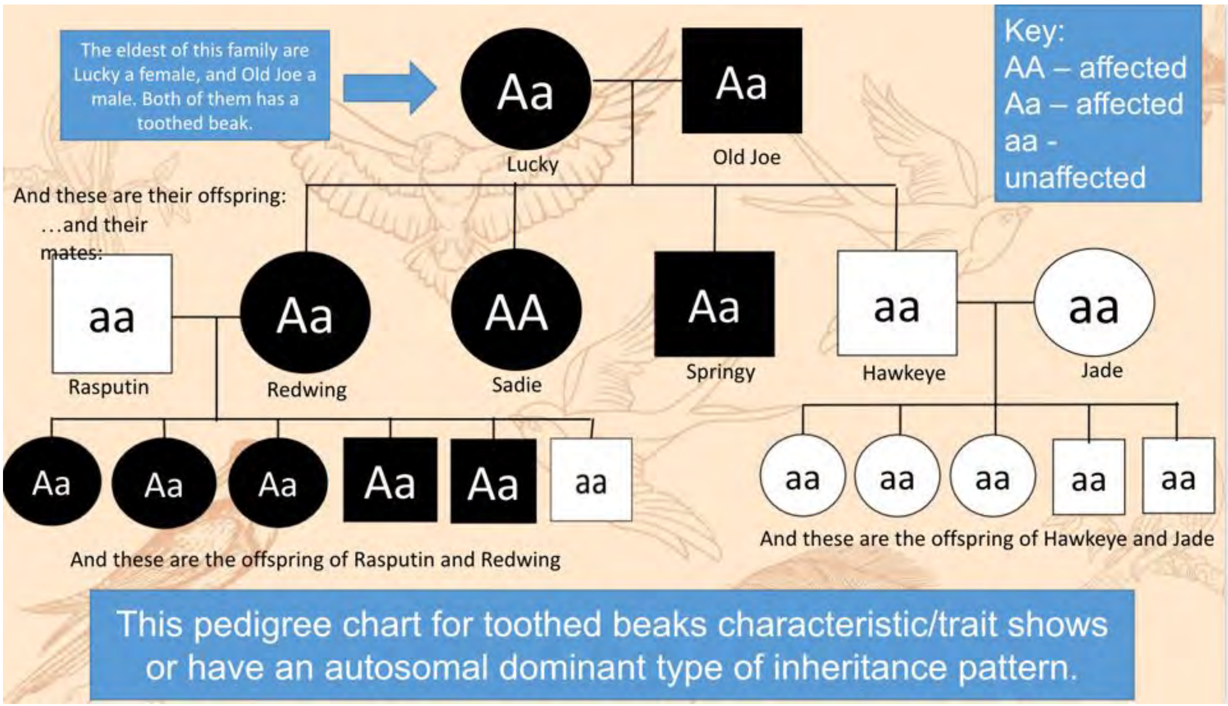
Sample of Students' Outputs for HBEs

HBE1 - Photosynthesis at-home Experiment

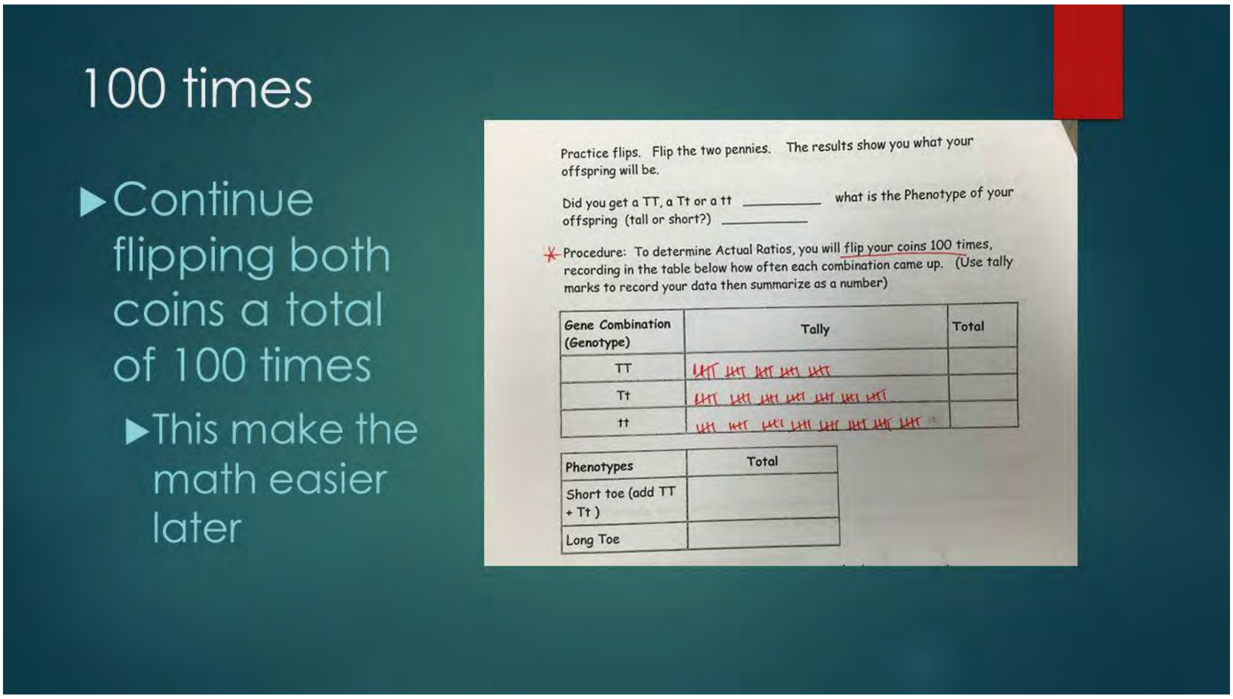
HBE2 - 3D Reproductive System Model



HBE3 - Building Pedigree Activity



HBE4 - Toss Your Genes



HBE5 - Edible DNA Model

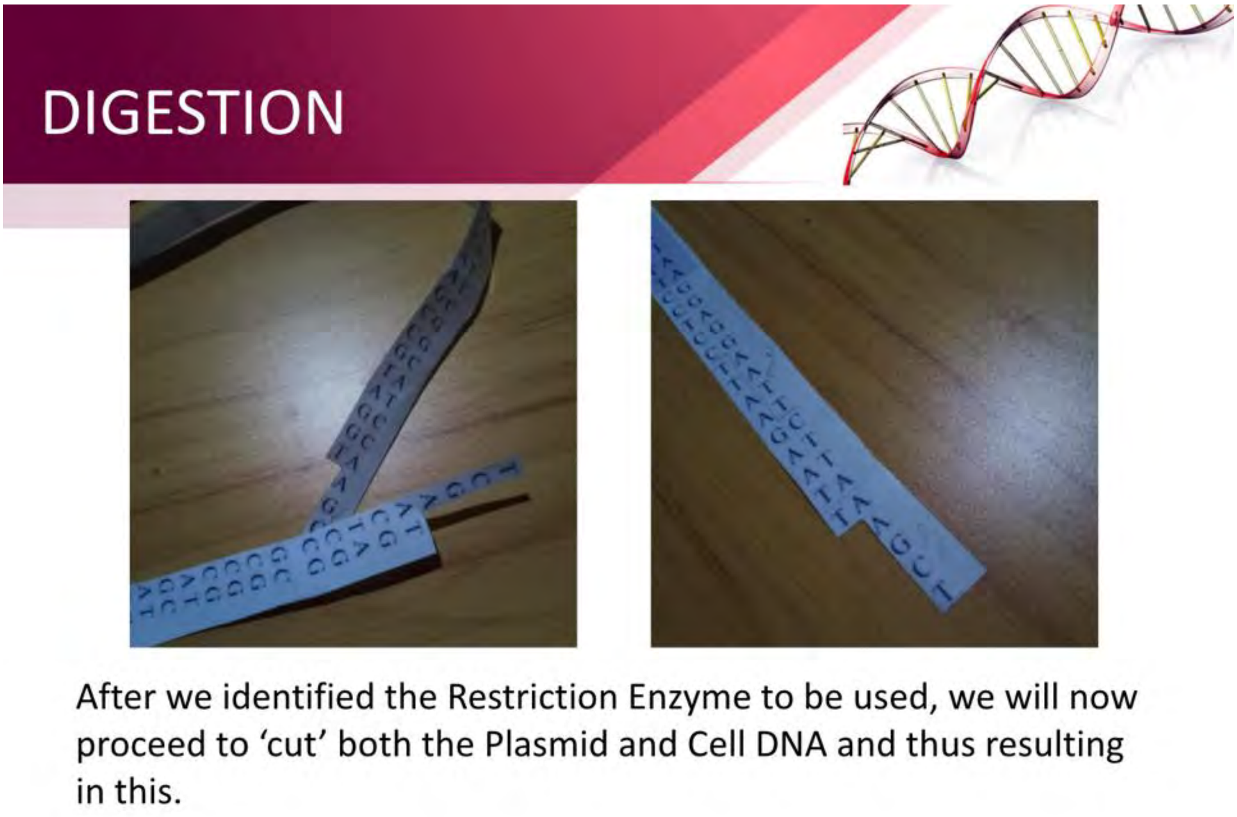
HBE6 - Chicken-Wing Dissection

HBE7 - Foldable Biological Levels of Organization

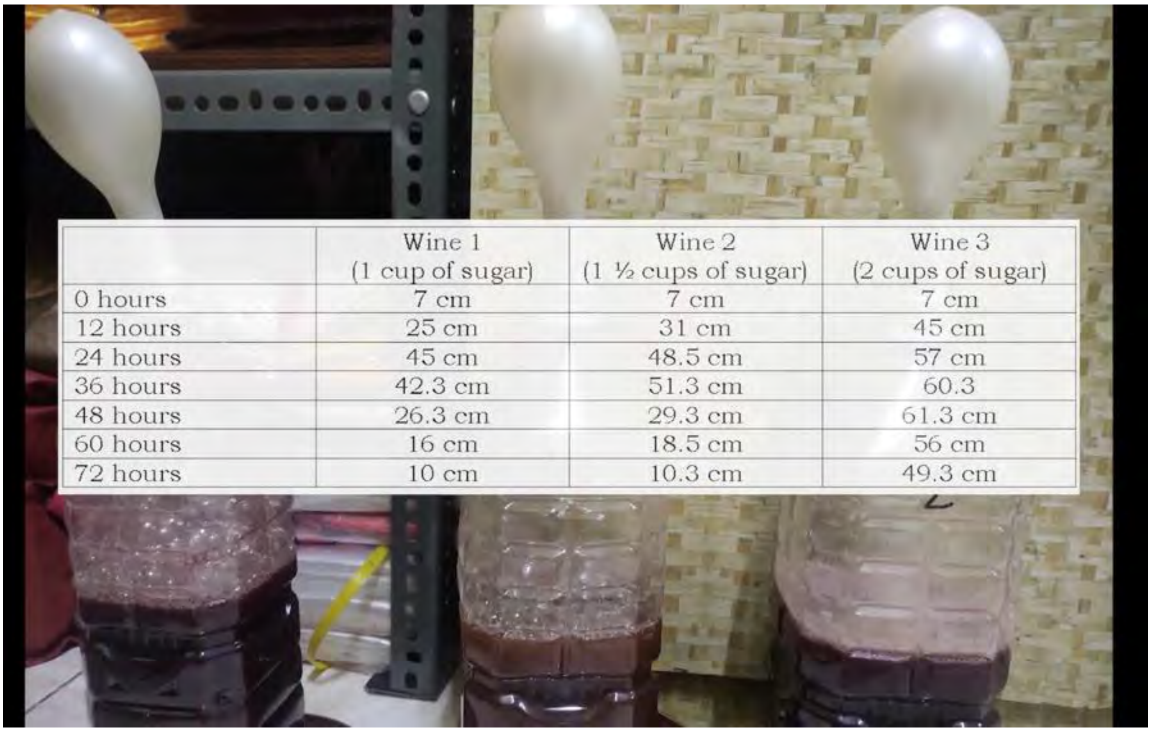
HBE8 - Backyard Biodiversity

Species	Phylum	Description of Habitat	Location
Dogs	Chordata	In nipa hut or grasslands	Backyard
Chickens	Chordata	A wood like cage or in grasslands	Backyard
Mushroom	Basidiomycota	Dark, cold and shady places	Backyard
Spider	Arthropoda	Spider web	Garden
Frog	Chordata	Under the trees	Garden
Butterfly	Arthropoda	Grasslands	Garden
Lizard	Chordata	Rocky areas or trees	Garden
Ptecticus	Arthropoda	In the leaf of a tree	Garden
Bees	Arthropoda	Beehive	Garden
Fire Ants	Arthropoda	Under the ground	Garden
Black Garden Ants	Arthropoda	Under the ground	Garden

HBE9 - Recombinant Paper Plasmid Experiment



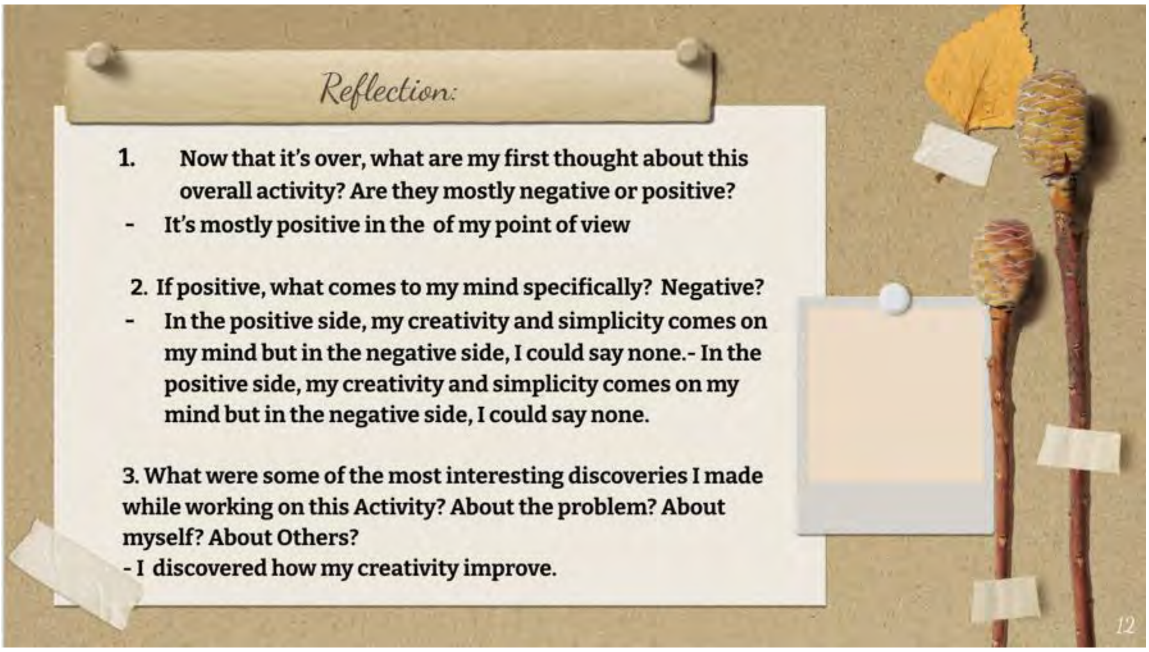
HBE10 - Yeast Balloons: Observing Cell Respiration



	Wine 1 (1 cup of sugar)	Wine 2 (1 ½ cups of sugar)	Wine 3 (2 cups of sugar)
0 hours	7 cm	7 cm	7 cm
12 hours	25 cm	31 cm	45 cm
24 hours	45 cm	48.5 cm	57 cm
36 hours	42.3 cm	51.3 cm	60.3
48 hours	26.3 cm	29.3 cm	61.3 cm
60 hours	16 cm	18.5 cm	56 cm
72 hours	10 cm	10.3 cm	49.3 cm

Appendix G

Sample of Students' Journal Entries and Reflections



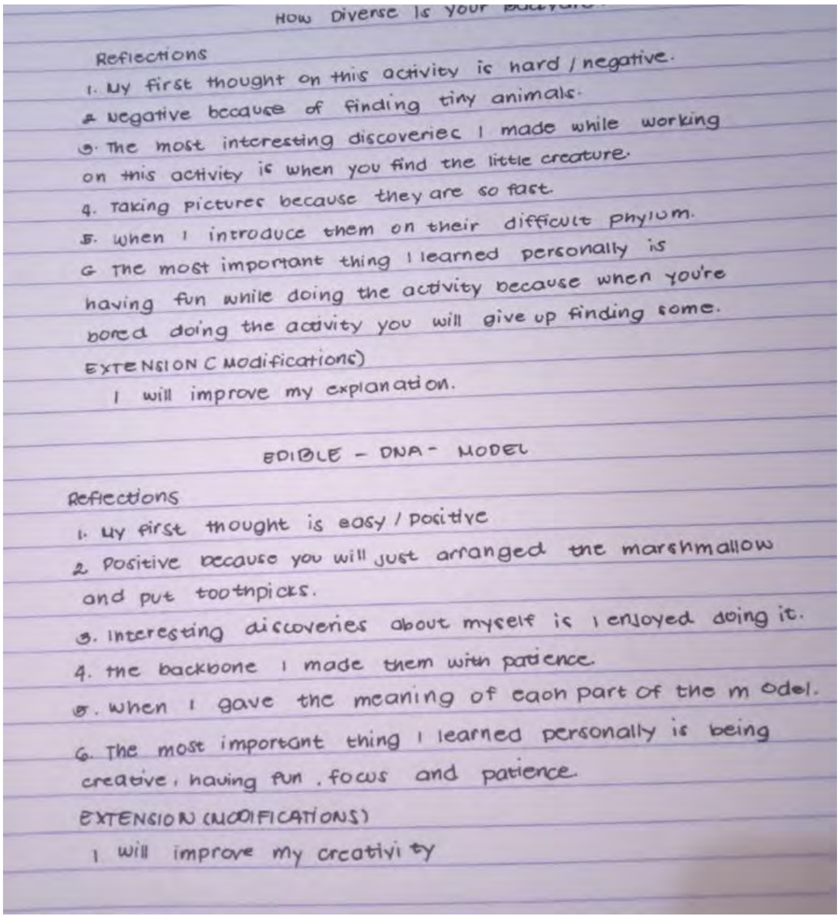
Reflection:

1. Now that it's over, what are my first thought about this overall activity? Are they mostly negative or positive?
- It's mostly positive in the of my point of view

2. If positive, what comes to my mind specifically? Negative?
- In the positive side, my creativity and simplicity comes on my mind but in the negative side, I could say none.- In the positive side, my creativity and simplicity comes on my mind but in the negative side, I could say none.

3. What were some of the most interesting discoveries I made while working on this Activity? About the problem? About myself? About Others?
- I discovered how my creativity improve.

12



HOW Diverse is your

Reflections
1. My first thought on this activity is hard / negative.
2. Negative because of finding tiny animals.
3. The most interesting discoveries I made while working on this activity is when you find the little creature.
4. Taking pictures because they are so fast.
5. When I introduce them on their difficult phylum.
6. The most important thing I learned personally is having fun while doing the activity because when you're bored doing the activity you will give up finding some.
EXTENSION (Modifications)
I will improve my explanation.

EDIBLE - DNA - MODEL

Reflections
1. My first thought is easy / positive
2. Positive because you will just arranged the marshmallow and put toothpicks.
3. Interesting discoveries about myself is I enjoyed doing it.
4. The backbone I made them with patience.
5. When I gave the meaning of each part of the model.
6. The most important thing I learned personally is being creative, having fun, focus and patience.
EXTENSION (MODIFICATIONS)
I will improve my creativity